Derivation of an Equation to Estimate Marrow Content of Mechanically Recovered Meat from Press Machines

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Background

Since 1995 when United States regulations made production of meat from advanced meat recovery (AMR) systems possible (USDA, 1994), the amount produced in the United States has risen to over 46,000,000 kg annually. The major advantages of AMR systems are recovery of up to an additional 4.5 kg of meat per beef carcass and a reduction in the risk of repetitive motion stress injuries to workers, notably, carpal tunnel syndrome.

Some have objected to production of meat from AMR systems because the meat contains trace amounts of bone powder and some bone marrow. As a result, the USDA (1998) proposed new rules to avoid misbranding and economic adulteration by limiting bone and marrow to levels consistent with defects anticipated when meat is separated from bone by hand. One problem with this proposal is that no accurate method to determine amount of marrow in mechanically recovered meat is available (Field, 1988; Pickering et al., 1995).

Objective

Our purpose was to derive an equation that makes an accurate determination of the amount of marrow in mechanically recovered meat from press machines possible.

Methods

Cervical vertebrae from four cow carcasses were selected at random from similar bones entering a Hydrau Separator HS 250A. The vertebrae were dissected free of all visible soft tissue but cartilage remained intact. Spinal cords had previously been removed from the vertebrae. The remaining cow cervical vertebrae entered the Hydrau Separator and were pressed at 200 bar for three seconds. Two bone cakes weighing approximately 16 kg each were selected from those being ejected and all bones in these cakes were dissected free of soft tissue. Intermediate lean pressed from bone cakes was transferred to a desinewing step where it passed between a belt and a drum with 1 mm holes that allowed the meat to pass through to the inner portion of the drum while sinew was separated. Weights of all lean, sinew and bone exiting the AMR system over a five minute period were recorded so that yield of lean could be calculated.

In a second test, bones from fed cattle approximately 18 to 24 mo of age were collected. Carcasses of these animals were USDA choice or select grades. Cervical vertebrae and the first four and one-half thoracic vertebrae with 12 to 15 cm long rib portions attached were selected at random from bones entering a Stork-Protecon TL-60 machine and dissected free of all visible soft tissue. As in the first test, the spinal cord was previously removed. The remaining cervical and thoracic vertebrae with rib portions attached entered the Stork-Protecon machine and were pressed at 170 bar for 2.3 seconds. Three bone cakes weighing approximately 9 kg each were selected at random and all bones in these cakes were dissected free of soft tissue. The desinewing step described previously for intermediate lean was followed. More detail on the AMR system has been given by the American Meat Science Association (AMSA, 1997). The major difference between meat from AMR systems and meat from mechanical recovery systems described previously (Field, 1988) is calcium content. The maximum amount of calcium allowed in meat from AMR systems is .15% compared to .75% for meat from previous mechanical recovery systems (USDA, 1994).

Cleaned bones before and after pressing from both tests were ashed at 600°C for 72 hours and the following equation (Gebault et al., 1998) was used to calculate marrow content:

Known: % ash in bone = 58.51; % ash in marrow = .57; % ash in cartilage = 2.14; wt of cartilage = bone wt x 9.5%; total wt = measured; total ash = measured

$$\text{wt of marrow} = \frac{\text{wt of cartilage (\% ash in cartilage - \% ash in bone) + \% ash in bone (tot wt) - (tot ash)}}{\text{(\% ash in bone - \% ash in marrow)}}$$

Results and Discussion

Composition of raw material entering AMR systems and composition of bone cakes is found in Table 1. In test I where cervical vertebrae from cows were studied, 42.7% of the raw material weight entering the Hydrau Separator HS 250A was lean and 57.3% was bone. Lean included all soft tissue on the outer surface of the cervical vertebrae and bone included cartilage and marrow. Lean in pressed bone cakes accounted for 26% of the bone cake weight. Therefore, 74% of the bone cake was pressed bone. Ash content of cleaned bones before and after pressing was 35.6% and 39.1%, respectively. In test I the equation of Gebault et al. (1998) showed that cleaned bones going into AMR systems contained 30.3% marrow. Cleaned bones from pressed cakes contained 24.3% marrow when the Gebault et al. (1998) equation was applied. Therefore, 6.0% marrow was removed from the bones during pressing. If we assume 100 kg of raw materials are pressed, 57.3 kg of bone would be present. A bone weight of 57.3 kg times 6.0% equals 3.44 kg of marrow removed leaving 53.86 kg of bone in the cake containing the remaining marrow. Therefore, the ratio of total unpressed bone to pressed bone with some marrow removed was obtained by dividing 57.3 by 53.86; the ratio was 1.0639.

The amount of marrow in meat from AMR systems may be determined by the following calculations:

Knowns:

1. $\text{total bone with lean} = \text{total bone} + \text{total lean}$

Dividing both sides of equation 1 by total lean yields:

2. $$\frac{\text{bone with lean}}{\text{total lean}} = \frac{\text{total bone + total lean}}{\text{total lean}}$$

Rearranging the terms and solving for lean gives:

3. $$\frac{\text{bone with lean}}{\text{total lean}} = \frac{\text{total bone}}{\text{total lean}} + \frac{\text{total lean}}{\text{total lean}}$$

4. $$\frac{\text{bone with lean}}{\text{total lean}} = \frac{\text{total bone}}{\text{total lean}} + 1$$

5. $$\frac{\text{bone with lean}}{\text{total lean}} - 1 = \frac{\text{total bone}}{\text{total lean}}$$

6. $$\text{total lean}\left(\frac{\text{bone with lean}}{\text{total lean}} - 1\right) = \text{total bone}$$

7. $$\text{total lean} = \frac{\text{total bone}}{\left(\frac{\text{bone with lean}}{\text{total lean}} - 1\right)}$$

To determine lean pressed from the bone cake we can write:

8. total lean = lean pressed from bone cake + lean remaining in bone cake

9. lean pressed from bone cake = total lean − lean remaining in bone cake

10. $$\text{lean pressed from bone cake} = \frac{\text{total bone}}{\left(\frac{\text{bone with lean}}{\text{total lean}} - 1\right)} - \text{lean remaining in bone cake}$$

11. *Marrow pressed from cake is calculated using:*
marrow pressed from cake = total bone – pressed bone
Replacing total bone by pressed bone times the ratio of total to pressed bone gives an equation with all variables known:

12.
$$\text{Marrow pressed from cake} = \text{pressed bone}\left(\frac{\text{total bone}}{\text{pressed bone}}\right) - \text{pressed bone}$$

Total yield of marrow and lean from the AMR press is easily obtained from expressions 12 and 10, respectively. An example of the calculations follows:
Assume 100 kg of bone cake. We know that 74 kg is pressed bone and the ratio of total bone to pressed bone is 1.0639. Therefore, equation 12 yields:
marrow pressed from cake = 74 (1.0639) – 74 = 4.73
Additionally, equation 10 gives amount of lean pressed from bone cake.

$$\text{lean pressed from cake} = \frac{78.73}{\left(\frac{100}{42.7} - 1\right)} - 26$$

lean pressed from bone cake = 58.75 – 26 = 32.75
Lean pressed from cake is called intermediate lean because it contains 6.8% sinew that is removed from the lean in an additional step. Therefore, yield of lean after removal of sinew = 32.75 x 932 = 30.52.
Percentage marrow in the AMR product is obtained as follows:
marrow pressed from cake + lean pressed from cake after sinew is removed = 4.73 + 30.52 = 35.25
marrow in AMR product = (4.73 ÷ 35.25) x 100 = 13.42%

Marrow in meat from AMR systems equaled 17.6% when the preceding calculations were followed using the means for test II in Table 1. Ash in clean bone and in clean pressed bone from younger animals was lower in test II when compared to test I but the amount of lean on the cow bones in test I was greater. Therefore, marrow content of lean from AMR systems is influenced by amount of lean on the raw material as well as amount of marrow in bones. Other factors expected to influence marrow content of AMR products include design of equipment, amount of pressure applied to the bone cake and length of time the pressure is applied. Nevertheless, we believe that the most important factors influencing marrow content of meat from AMR systems are marrow content of the bones and amount of lean in the raw material.

Marrow content of bone and amount of lean attached to the bone vary with anatomical location and age of animals so the values calculated in this study may not apply to other lots of meat from AMR systems. A further caution is that marrow content of cow bones can vary widely because cows often range from 2 to 12 years of age at the time of processing. Other factors such as calcium content of the diet and lactation might also influence marrow content of cow bones. Therefore, the values for marrow in meat from AMR systems are preliminary and may not be accurate reflections of the amount of marrow in other sources of beef from AMR systems.

Conclusions

Correct values for marrow content of meat can be obtained by cleaning representative bones entering and exiting AMR systems and determining their ash content. Once the actual amount of marrow in meat from AMR systems is known, quality control measures that are much less labor intensive than methods used in this study can be established.

References

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Table 1. Composition of Raw Material Entering AMR Systems and Composition of Bone Cakes.

Item	Test I, Cows[a] Mean	Test I, Cows[a] SD	Test II, Select and Choice[d] Mean	Test II, Select and Choice[d] SD
Lean on bones, %[b]	42.7	3.2	36.0	2.0
Ash in clean bone, [c]	35.6	2.1	33.5	2.4
Marrow in clean bone, %	30.3	----	33.9	----
Lean in pressed bone cakes, %	26.0	1.2	22.0	1.2
Ash in clean pressed bone, %[c]	39.1	.5	37.6	.5
Marrow in clean pressed bone, %	24.3	----	28.3	----
Marrow in meat from AMR system, %	13.4	----	17.6	----

[a] Based on seven cervical vertebrae pressed at 200 bar for 4 seconds using a Hydrau Separator HS 250A. Intermediate lean contained 6.8% sinew that was removed in an additional step.
[b] Lean includes all soft tissue dissected from bones.
[c] Means were used in the equation of Gebault et al. (1998) to obtain marrow content of bones.
[d] Based on seven cervical and four and one-half thoracic vertebrae, pressed at 170 bar for 2.3 seconds using a Stork-Protecon TL-60. Intermediate lean contained 12% sinew that was removed in an additional step.